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THE CITRUS INSECTS OF JAPAN

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INTRODUCTION

To the citrus-fruit growers of the United States any bulletin is of value which lists the insects infesting citrus and related plants in other countries, in that it places on record the species which are capable of becoming pests under favorable conditions, and against which continued vigilance must be exercised in order to prevent their introduction and establishment in America. Many of these insects might not otherwise be recognized in their proper rôle until too late for the employment of effective eradication or restrictive measures.

Various publications in Japan contain data on certain of the citrus pests of that country; yet, because of the difficulties of translation, these are inaccessible to workers who do not read Japanese. The purpose of this bulletin is to assemble these data, combine them with such as have been obtained by personal observation, and thus present in concise form a fairly complete list of the species known to attack citrus, and such facts regarding them as may be of general interest.

During the seasons of 1916 and 1917 the writer, as an agent of the California State Commission of Horticulture, was engaged in the study of the citrus insects of Japan, Formosa, southern China, and the Philippine Islands, and in the importation into California of such parasites and predators as seemed to hold promise of value

[1] The writer wishes to express his thanks to S. I. Kuwana for much information regarding the insects dealt with in this bulletin and for the determination of a number of the species collected.

against the species of scale insects then occurring in that State. During this period a considerable quantity of data was secured, both by personal observation and through the entomologists connected with the various agricultural experiment stations. This information has been supplemented during the seasons of 1920 to 1923, inclusive, by such investigations as it was possible to make while engaged on other projects. Practically every citrus-growing section was visited during this time, and a brief discussion of the insect pests observed is given in the following pages.

The citrus-producing sections of Japan proper extend from slightly below Tokyo, at the center of the main island, southward to the island of Kiushu, the most extensive plantings being in the Prefectures of Wakayama and Shizuoka. The total area devoted to citrus is approximately 75,000 acres, planted largely to the so-called Satsuma, or Unshu, orange. Pomelos are grown extensively, and navel oranges are coming into favor in certain districts, but as yet very few lemons are being grown, and these few near Hiroshima.

ORIGIN AND HISTORY OF CITRUS CULTURE IN JAPAN

A short account of the introduction of this fruit into Japan and of the development of the citrus industry may be given, as it has a bearing upon the introduction of various insect pests now present, and their development and distribution.

It has generally been assumed that the cultivation of this fruit in Japan dates back only about 300 years, at which time, presumably, the original stock was brought over from the Asiatic mainland. However, according to K. Hisauchi, there is in the Kojiki, the earliest written history of Japan (compiled A. D. 712), reference to several expeditions to the mainland for the purpose of obtaining this fruit. Also the Hitachi Fudoki (A. D. 713) contains an account of the production of citrus fruits in Hitachi Province. It is thus evident that citrus has been grown in Japan for at least 13 centuries, though its production on a large scale for commercial purposes may have been a comparatively recent development. Individual trees are known which, according to records, are at least 300 years old and have changed little during that time.

If it were certain that all of the varieties of citrus now present in Japan were introduced, even though in remote times, it might be assumed with some degree of certainty that those insects which are strictly confined to the genus as host have likewise been introduced, probably in connection with importations of fruit and plants. According to some Japanese botanists, however, a wild form of *Poncirus nubilis* occurs in central Shikoku, and some of the native pests may have gone from this to the cultivated varieties.

As citrus is now an old established fruit in Japan, and as fresh stock has been brought in at frequent intervals from China and other sections of the Orient, it is to be expected that many of the pests of these countries may likewise have been brought into the country and established there. During the intervening centuries many of these species have reached the point of equilibrium and may be considered as of the same status as the native forms. As is noticeable among the citrus insects of Florida and California, practically all of the very injurious forms, particularly among the scale insects,

have been introduced, and in comparatively recent times. In general this holds true of the insects of economic importance in all countries.

Climatic conditions undoubtedly exert a marked influence upon the development and increase of any insect species, and its status as a pest may be largely determined by these factors. In contrast to California, with its long, dry summer season, summer in Japan is very humid throughout and is characterized by very frequent rains. Thus the climate corresponds much more closely to that of Florida and the Gulf coast in general, and it is consequently to be expected that any given species will develop more nearly along the same lines in Japan and Florida, and along considerably different lines in California. This point will be illustrated more fully in the discussion of certain of the scale insects.

THE SCALE INSECTS AND WHITE FLIES

In Japan, as in America, the scale insects and white flies, particularly the first, represent a marked majority of all the insect species injurious to citrus trees. The number of species is unusually large, and among them are many which are exceedingly injurious. Those of major importance attacking citrus in Japan at the present time are as follows:

The yanone scale	*Prontaspis yanonensis* (Kuw.).
The red wax scale	*Ceroplastes rubens* Mask.
The orange Pulvinaria	*Pulvinaria aurantii* Ckll.
The chaff scale	*Parlatoria pergandii* Comst.
The aspidistra scale	*Pinnaspis* (*Hemichionaspis*) *aspidistrae* (Sign.).
Glover's scale	*Lepidosaphes gloverii* (Pack.).
	Aleurocanthus spiniferus (Quaint.).
	Aleurolobus marlatti (Quaint.).

Not a single one of these major pests of Japan is present as such in the groves of California. Only one of them (*Lepidosaphes gloverii*) is native to the islands, the remainder having been introduced from other countries.

The species which are commonly or occasionally found upon citrus but which are of little or no consequence from the economic point of view are:

The citrus white fly	*Dialeurodes citri* (Ashm.).
The cottony cushion scale	*Icerya purchasi* Mask.
	Icerya seychellarum (Westw.).
The camphor scale	*Pseudaonidia duplex* (Ckll.).
The Florida wax scale	*Ceroplastes floridensis* Comst.
The citricola scale	*Coccus pseudomagnoliarum* (Kuw.).
The black scale	*Saisettia oleae* (Bern.).
The purple scale	*Lepidosaphes beckii* (Newm.).
The California red scale	*Chrysomphalus aurantii* (Mask.).
The yellow scale	*Chrysomphalus aurantii* var. *citrinus* (Coq.).
The common mealy bug	*Pseudococcus citri* (Risso.).
	Pseudococcus spp.
The soft brown scale	*Coccus hesperidum* L.
	Takahashia citricola Kuw.
	Takahashia japonica (Ckll.).
	Pulvinaria citricola Kuw.
The San Jose scale	*Aspidiotus perniciosus* Comst.
The Florida red scale	*Chrysomphalus aonidum* (L.).
	Leucaspis japonica Ckll.
	Bemisia giffardi (Kotinsky).
	Aleurocanthus sp.

This second list includes, with the exception of *Pseudococcus gahani* Green, all of the scale insect pests of California and most of those of Florida as well. While in some cases it might be said that the failure of the species to become serious pests in Japan is due to the comparatively recent date of introduction, yet a considerable number of them have been present in small colonies for a long period of years, and have shown no indication of increase or spread. This is particularly true of several of the species that are most injurious in California.

In taking up the species individually, consideration may first be given to the yanone scale (*Prontaspis yanonensis* (Kuw.)) (fig. 1), the most injurious insect pest of citrus in Japan. This is what was

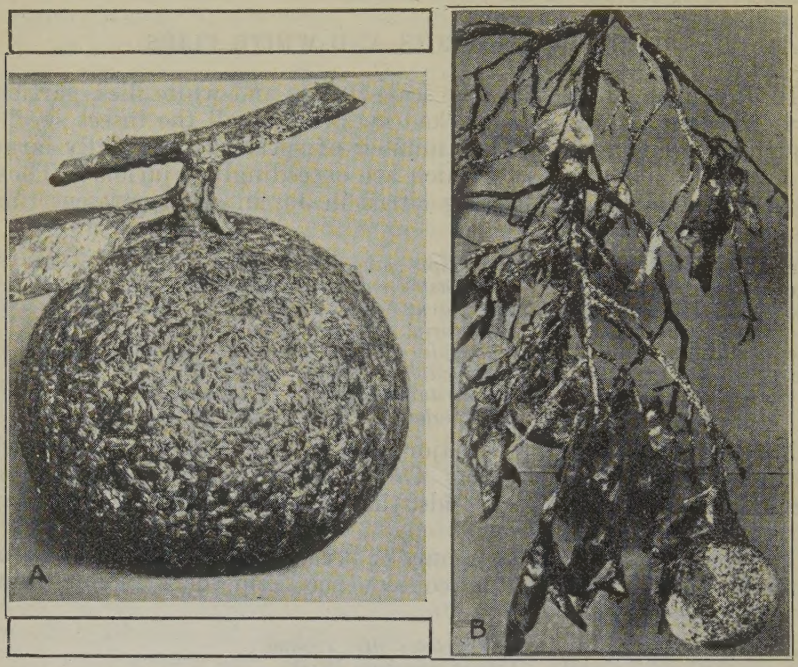

FIG. 1.—The yanone scale (*Prontaspis yanonensis*): A, a heavily infested orange; B, a twig showing injury due to attack by the scale. The white masses are male puparia (Kuwana)

recorded from that country until recently as the true orange Chionaspis (*C. citri* Comst.). It has recently been studied in detail by S. I. Kuwana (*4, p. 29*) [2] and in 1923 described as a new species under the name of *Chionaspis yanonensis* (*6*) and later in the same year (*7*) transferred to Macgillivray's new genus Prontaspis.

This species is presumably a native of continental Asia, as it is frequently taken at quarantine on fruit from southern China, and was first found in Japan near Nagasaki in 1907. It has now been distributed throughout Kiushu and to several points in Honshu, the main island, as well. Its spread has therefore been very rapid, and it is probable that the entire citrus belt will be infested within a

[2] Numbers in parenthesis in italics refer to "Literature cited," p. 15.

comparatively short time. The true orange Chionaspis (*Prontaspis citri* (Comst.)) does not occur in Japan.

The effect upon the trees of a heavy infestation of the yanone scale is very similar to that of the purple scale (*Lepidosaphes beckii* (Newm.)) in California. In the vicinity of Nagasaki many trees have been killed, and a large proportion of the infested groves have been seriously injured. Infested trees may be recognized at a distance by the large masses of white male cocoons present on the foliage and twigs. The greater proportion of the female scales are found upon the twigs and smaller branches, but many settle upon the fruit as well. As three generations are produced each year there is a very rapid increase in numbers.

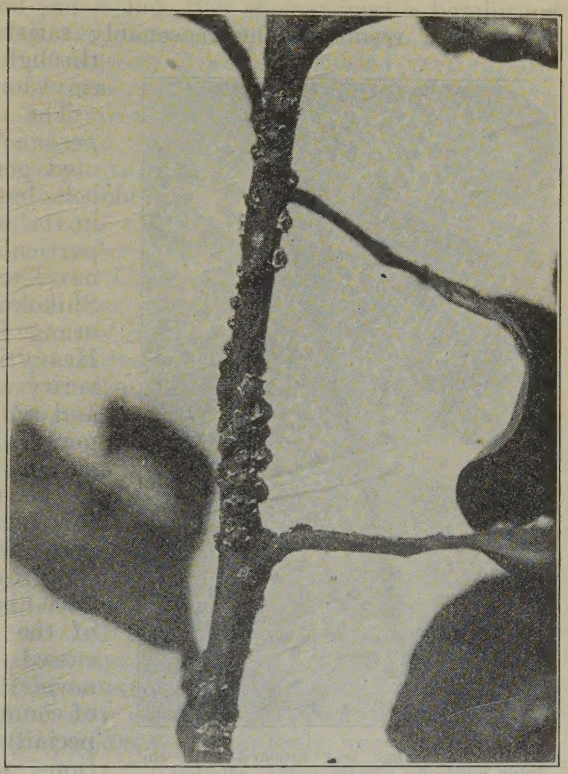

FIG. 2.—An orange twig bearing adult females of the red wax scale (*Ceroplastes rubens*)

The red wax scale (*Ceroplastes rubens* Mask.) (fig. 2) ranks next to the foregoing species in the degree of injury inflicted. It was first found at Nagasaki in 1897, and since that time it has spread throughout the island of Kiushu and also to many widely separated points in Honshu. It is now too widely distributed to permit of eradication, or even of effective restriction, and, like the previously mentioned species, it is almost certain to cover the entire citrus belt in the near future. Its increase has been even more rapid than that of the yanone scale, and though the wax scale apparently became established only about 10 years earlier, yet it now covers a much greater area. Only one generation is produced each year, and maturity is reached during the late spring months. The females assemble largely on the young twigs, and occasionally on the fruit and foliage. A heavy infestation is comparable to that of the black scale (*Saissetia oleae* (Bern.)), a considerable proportion of the injury being due to the black fungus which develops in the honeydew and prevents the proper functioning of the leaves. Unlike that of the yanone scale, its feeding is not followed by any toxic effect on the tree.

The orange Pulvinaria (*P. aurantii* Ckll.) is very common throughout the citrus belt and can be found in varying numbers on practically every orange tree. At times it becomes excessively abundant, and the enormous quantity of honeydew excreted provides a medium for the growth of a dense mat of sooty-mold fungus, with the same effect as that caused by the wax scale, and, in addition, the prevention of the proper and uniform ripening of the fruit. In heavy infestations this honeydew is exuded so copiously as to give the appearance of a light mist falling from the tree, rather strikingly noticeable in strong sunlight. Formerly this species was considered a very serious pest, but it has now decreased in importance as a result of the reasonably satisfactory control effected through the use of kerosene emulsion.

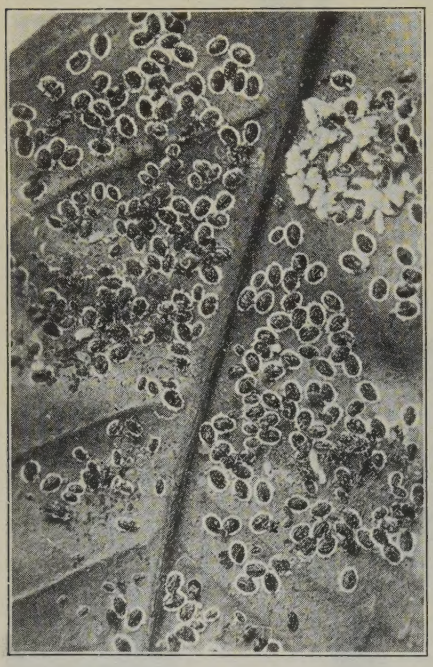

FIG. 3.—An orange leaf infested with the spiny white fly (*Aleurocanthus spiniferus*)

The chaff scale (*Parlatoria pergandii* Comst.) is distributed generally over the citrus belt, but is a serious pest only in the southern sections. It is particularly abundant upon the navel orange on the island of Shikoku and upon the Unshu orange in the vicinity of Osaka. Heavy infestations rank in severity with those of the yanone and red wax scales, though in general they are much less severe.

The remaining two species listed among the major scale pests are usually abundant in the groves, but the injury produced is not comparable to that of the species previously discussed. *Pinnaspis* (*Hemichionaspis*) *aspidistrae* (Sign.) is of common occurrence, more especially in the southern sections, and at times it heavily infests the Unshu orange. Glover's scale (*Lepidosaphes gloverii* (Pack.)) is also of general distribution and at times becomes a serious pest. During certain seasons, particularly that of the summer rains, great numbers of the scale are killed by a red fungus.

Among the white flies, *Aleurocanthus spiniferus* (Quaintance) (fig. 3) is the most injurious of the four or more species known to infest citrus in Japan. At present it is abundant only in the general vicinity of Nagasaki, but it is spreading very rapidly and small colonies have been found in many sections of Kiushu. At Nagasaki the infestation is very heavy, and the species gives evidence of very soon ranking with the yanone and red wax scales in importance. Another species (*Aleurolobus marlatti* (Quaintance)) is also established at Nagasaki and bids fair to keep pace with the first mentioned.

The citrus white fly (*Dialeurodes citri* (Ashm.)) may at times be found in various sections ranging from Tokyo to Nagasaki, but in only a few instances has it been observed upon citrus trees, and then only in very small numbers. Usually the host is the common English ivy or some other ornamental. It is known to have been present for many years but shows no indication as yet of becoming a serious citrus pest.

Among the scale insects of lesser importance the well known cottony-cushion scale (*Icerya purchasi* Mask.) may be mentioned first. As in California, this species was once of primary rank as a citrus pest. It appeared first at Shizuoka in 1904 on nursery stock imported from America, and about the same time infestations were found which could be traced to Formosan origin. It spread very rapidly and soon became the most serious pest confronting the citrus growers. According to Kuwana, in Japan three generations are produced each second year and only two in the alternate years, whereas in Formosa there are three generations annually. In 1912 colonies of *Novius cardinalis* Muls. were obtained from Formosa, into which they had been imported from California some years previously. These were reared in large numbers for field distribution, particularly at the insectaries at Shizuoka. This was continued for a number of years, and the same success was attained as has resulted in other countries into which this coccinellid has been introduced to check the pest. A full report on this project was published in 1917 (*5*). At the present time occasional small infestations may be found, but they are not widespread and are soon brought under control.

Another species of this genus (*I. seychellarum* (Westw.)) may at times be found in the groves, but the outbreaks are only sporadic and rather infrequent. This species is very heavily parasitized by the agromyzid fly *Cryptochaetum grandi* Rondini.

The camphor scale (*Pseudaonidia duplex* (Ckll.)), which is now becoming such a serious pest in the Southern States, is of general distribution throughout the citrus belt of Japan, and may be found in almost every grove, as well as in the pear orchards. In no instance has it been observed upon orange in sufficient numbers to cause injury, though certain ornamental plants, such as azalea and camellia, may bear fairly heavy infestations. Incidentally, it was only in 1923 that the first specimens of this scale were found upon camphor in Japan, these being noted by Kuwana upon a small tree at Osaka.

The Florida wax scale (*Ceroplastes floridensis* Comst.) is in habit and life history very similar to the red wax scale, previously discussed, but does not occur in sufficient numbers upon citrus to be considered a pest. Like the latter species, it occurs at times in large numbers upon the tea plant (*Thea chinensis*), though the favorite host plant is *Evonymus japonica*, upon which it may be found abundantly in all sections from Tokyo southward. The numerous parasites which attack it serve to make the infestations only sporadic, these seldom persisting over a period of more than three years. Strangely enough, none of these parasites have thus far been observed attacking *C. rubens*, though the physical similarity of the two species would seem to permit of ready development upon either.

The citricola scale (*Coccus pseudomagnoliarum* (Kuw.)) of California was first recognized in Japan at Okitsu by the writer in

1916, and since that time has been noted in widely separated localities ranging from Tokyo to Nagasaki. It is therefore of wide distribution and undoubtedly has been established for a long time, though originating probably in continental Asia. Observations were continued on the species, and in 1923 (*1*) it was finally determined as being identical with the California form. The California infestation is very probably of oriental origin, as considerable quantities of citrus stock have been imported from the East in past years. The scale is of no consequence whatever as a citrus pest in Japan, as only isolated individuals can be found in the groves. Occasionally fair colonies may be observed on the trifoliate orange (*Poncirus trifoliata*) but these seldom persist for more than one or two seasons. The young and half-grown scales are parasitized quite extensively by *Coccophagus yoshidae* Nakayama and by several other chalcids, and the adult females are destroyed in numbers by *Chilocorus similis* Rossi and other coccinellids.

The black scale (*Saisettia oleae* (Bern.)), which has become established in a small planting of olive trees near Okitsu, originated in a shipment of cuttings brought over from California in 1908. At the present time the scale may be found in relatively small numbers on these few olive trees and has increased very little. Curiously enough, though these olive trees were interplanted among various varieties of citrus, none of the latter have become infested. The writer examined this grove frequently during more than seven years and did not succeed in finding a single scale upon citrus. A small infestation was observed upon ornamentals in a greenhouse at Sapporo, Hokkaido, during 1921.

The purple scale (*Lepidosaphes beckii* (Newm.)) is known to occur in a grove near Okitsu, but not elsewhere. It has been present for a considerable number of years, yet shows no indication of increase to the extent known in California. The presence of this, as well as of the previously mentioned species, in such restricted areas would seem to justify eradication measures, but because of their present harmless status little attention has thus far been paid to them.

The red and yellow scales (*Chrysomphalus aurantii* (Mask.) and variety *citrinus* (Coq.)) have also been observed in small numbers in widely separated sections, but in no instance in sufficient numbers to attract attention.

The most common of the mealybug species occurring upon citrus is apparently as yet undescribed. It may be found in nearly every grove, though very seldom in sufficient numbers to cause injury. The individuals of this species have the habit of assembling within leaves which have curled because of injury from the yanone scale, an aphis, or the tunneling of the lepidopterous leaf miner *Phyllocnistis saligna* Zell.

The so-called Japanese mealybug of California (*Pseudococcus krauhiae* Kuw.) is not known to occur in Japan. It was originally described from specimens taken from nursery stock at Yokohama which had been imported from China. Extensive observations since that time by Kuwana, who described the species, and others, have failed to discover it in Japan, though it was noted in considerable numbers in southern China by the writer in 1916.

The remaining species of scale insects and white flies listed among those of lesser importance are of only infrequent occurrence, and are mentioned merely because they are occasionally met with on citrus.

FRUIT FEEDERS

Fruit feeders may be considered the three species of noctuid moths, two tortricids, and one pyralid, which inflict more or less injury upon the fruit by their feeding. The noctuids comprise the following species: *Ophideres tyrannus* Guen., *Calpe excavata* Butl., and *C. capucina* Esq., all of which are similar in habit, though the first named is by far the most injurious. The adult moths insert the proboscis into the green fruit for the purpose of feeding, after which decay soon sets in, and the fruit eventually drops from the tree. *O. tyrannus* is very abundant in the southern sections and is particularly injurious to the navel orange, for which reason this variety can not be grown extensively in Kiushu and Shikoku. In the case of the Satsuma orange the percentage of fruit attacked is not large enough to warrant control measures. Even with the navel orange such measures have not as yet been attempted, and the nature of the problem presents very serious difficulties in the way of development of a practical remedy. In the immature stages all of these species feed upon plants other than citrus, the larvae of Ophideres, for instance, being found only upon akebia (*Akebia quinata*). It is possible that this pest might be controlled by the elimination of the food plant just mentioned if such were practicable.

The pyralid moth *Dichocrocis punctiferalis* Guen. lives in its larval stage within the fruit somewhat after the manner of the codling moth (*Carpocapsa pomonella* L.) in apples. The burrows naturally give rise to decay, causing the still green fruit to fall from the tree. The injury to citrus, however, is not general as compared with that to peach, chestnut, etc. Two generations are produced each year. This species is recorded as a serious pest in castor-bean pods in India and on teak in the Dutch East Indies.

Two tortricids, the most common of which is *Cacoecia podana* Sc., bore into the fruit in the larval stages, but neither of them is sufficiently abundant in the citrus-growing sections to produce injury of consequence.

LEAF MINERS, LEAF ROLLERS, AND GENERAL FEEDERS

One of the most important among all of the insects attacking citrus in Japan is the small lepidopterous leaf miner *Phyllocnistis saligna* Zell. (fig. 4), which causes extensive injury in all of the citrus-producing sections. It is said by some to have three generations a year, but Kurisaki (*3*) in recording the life history mentions seven as probably being the normal number. The winter is passed in the adult stage, and in the spring these adults emerge from their hibernating quarters and oviposit on the young and tender foliage and twigs which have just been developed. The larvae work their way beneath the epidermis and form a very characteristic serpentine tunnel through the tissue of the leaf or shoot. These burrows are usually, though not always, on the underside of the leaves. On the young and tender leaves thus attacked the surface tissue dies and

the leaves curl, assuming much the appearance of those heavily infested with aphids. The burrows serve as points of infection for citrus canker. This fact has also been noted in the case of a related species (*Phyllocnistis citrella* Stainton) in Australia (*2*). This latter species is very injurious to nursery stock in India and, as would be expected, is particularly injurious to nursery stock in Japan, especially during the spring months, when the new foliage is being developed. Often practically every leaf and young shoot contains one or more of these miners, and the injury to the young tree is consequently very great, in some nurseries so severe as to render the plants useless for propagation purposes.

Efforts have been made to find a practical means of controlling this pest, but with indifferent results. In the nurseries, however,

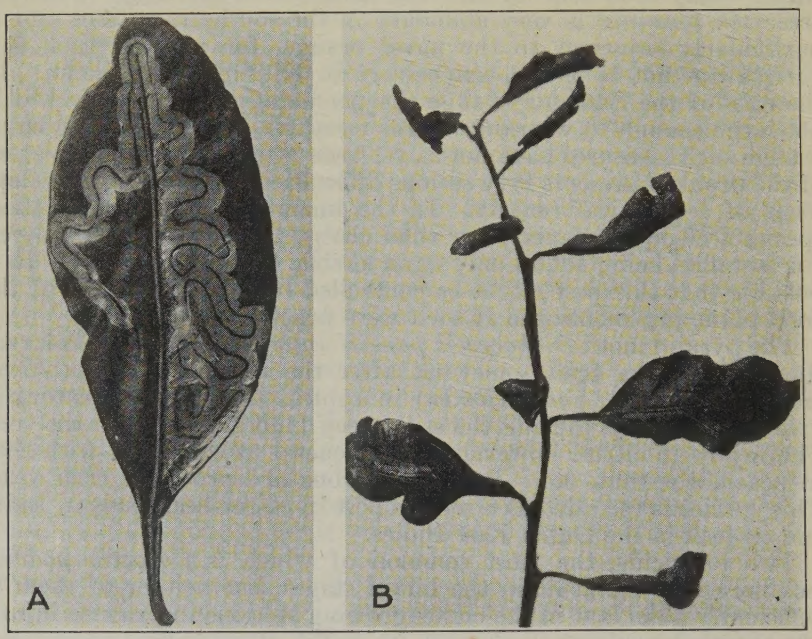

FIG. 4.—The citrus leaf miner (*Phyllocnistis saligna*): A, leaf showing the characteristic serpentine tunnel; B, twig with leaves curled due to attack by the miner

its activities are considerably reduced by the use of additional phosphorus and less nitrogen in the fertilizer applied, this tending to retard the formation of foliage during the early part of the season.

The leaf roller *Depressaria culcitella* Hg. is common throughout the citrus-growing sections but is never a serious pest. The larvae feed upon the foliage and then roll a portion of the leaf to form a pupation chamber. Two or three generations are produced each year. Two additional species with identical habits are known to occur, but they are comparatively rare.

Several species of butterflies are known to feed, in their larval stages, exclusively upon citrus. These are of the genus Papilio, and the most important one (*P. xanthus* L.) is commonly found throughout the citrus belt. In the groves the damage is ordinarily incon-

sequential, but in the nurseries a sufficient quantity of foliage may be consumed to act as a serious check upon the growth of the young trees.

FRUIT FLIES

Only one species of orange fruit fly has thus far been found in Japan, and this (*Dacus tsuneonis* Miyake) is limited in its distribution to portions of the island of Kiushu. An extensive study of the species was made by the late T. Miyake (*8*), and his findings indicate that the fly is a native insect and at times becomes quite a serious pest. The fruit becomes infested generally during August and usually drops from the tree by the time the larvae have matured, in October or November. One or two days thereafter the larvae emerge and enter the soil, where pupation takes place. This stage persists until the following June or July, when the adult flies appear. Oviposition begins a few weeks later.

In most localities the damage occasioned by the attack of this fruit fly is not great, being usually less than 10 per cent. The heaviest infestations bring about the loss of from 40 to 50 per cent of the total crop, and occasionally more. This is limited, however, to a few localities.

The methods of control employed consist of the destruction of fallen and infested fruit, and the collection of adult flies prior to, and during, the period in which oviposition takes place. In some places this is done under the direction of the district officials and takes place at least five times each season. The captured flies are turned in to the local Government office and are paid for at the rate of one-tenth to one-fourth of a cent each. Thus, in one village a total of 200,000 were collected at a cost of approximately $400. It is said that these collections have materially reduced the number of orange flies in the districts in which they are made.

THE TRUNK BORER

Although not abundant numerically as compared with the other pests previously discussed, this cerambycid beetle (*Melanauster chinensis* Forster) was frequently, in former times, the cause of considerable loss to the citrus growers. The adult beetles appear in the field during the month of June, and oviposition takes place during the latter part of the summer, at which time the eggs are placed in the bark of the trunk near its base. Upon emerging, the larvae work their way into the woody tissues of the trunk and roots. As growth takes place the burrows are naturally increased in size, and only a few larvae are required to bring about the death of the tree. A portion of the injury attributed to this insect is really due primarily to other factors, the beetle then attacking the weakened branches or trunk. Mulberry, fig, and other trees as well as citrus are attacked. The life cycle presumably extends over a period of three years. The main control measure thus far practiced in Japan is the collection of the adult beetles by children during the summer season, prior to oviposition. Apparently fairly satisfactory results are obtained in this way.

This species was observed to cause considerable damage in southern China, it in fact being the most injurious insect attacking citrus in

the sections visited. The method of control there used was to insert a sharp wire into the burrow and twist it about until the larva was located and killed.

MISCELLANEOUS CITRUS PESTS

In addition to the pests already mentioned, there are a few others which also might be included. A fulgorid (*Geisha distinctissima* Wk.), which feeds largely upon the newly developed leaves, is a common but not a serious pest. Red spiders and mites are frequently seen, and during dry seasons cause some damage, but never any damage comparable to that in certain sections of the United States. The orange rust mite (*Eriophyes oleivorus* Ashm.), an introduced form, is often met with, and during dry seasons may produce some injury, particularly in the southern sections. Certain fruit venders in Kiushu specialize in the sale of fruit damaged by this mite, and the claim is made by them that the flavor is superior to that of normal fruit. An undetermined species of thrips is found in some sections upon citrus, feeding almost exclusively upon the blossoms, and occasionally occurring in such numbers as to prevent the proper setting of the fruit. A scarabaeid beetle (*Oxycetonia jucunda* Folderm.) in its adult form also feeds at the blossoms and at times produces a similar injury. As elsewhere, aphids are frequently very abundant during the early spring, but these do not differ in degree of infestation or in the manner of attack from those on citrus in other parts of the world.

FACTORS BEARING UPON THE CONTROL OF CITRUS INSECTS IN JAPAN

The control of citrus insects in Japan in an economical and practical way is rendered difficult by several factors which ordinarily do not enter into the problem in the United States. The average grove comprises less than 100 trees, so that the purchase by individual growers of expensive equipment is out of the question. It may be said that in California the problem is relatively simple in that all of the major pests are scale insects, which are controlled by a fumigation every two years or, in the case of certain species, several times each year. In Japan some of the scale insects are not amenable to fumigation, and, in addition, other pests fully as serious as the scales must be reckoned with. In the past there has been considerable objection on the part of the growers to the use of chemical sprays for the control of fruit insects, but this is gradually being overcome.

Besides the small size of the groves, an added difficulty in control is presented by the fact that the greater proportion of citrus are planted on terraced hillsides (fig. 5), which renders impracticable the use of horse-drawn fumigating machines or spray tanks. As there are only a few trees on each terrace, and these are irregularly placed, the shifting of tents in fumigation involves much labor, though this is somewhat offset by the much smaller size of the trees as compared with those in America. In general it may be said of fumigation that it is practiced to a very limited extent, is very expensive, and is less effective than in those countries where it has been placed on a sound commercial basis.

Spraying with hand pumps is often practiced, but more particularly against diseases. The orange Pulvinaria is controlled generally by the use of kerosene emulsion, but in by far the greater proportion of groves no attempt whatever is made to control the insect pests. In the case of certain deciduous fruits each one is inclosed, shortly after setting, in a paper bag, but this is never practiced with citrus.

The praticability of insect control is naturally closely bound up with the margin of profit it is possible to attain with the particular crop under consideration. The financial return from a first-class citrus grove in Japan is about comparable to that in California, with the average for a period of years possibly higher. The complete loss of a year's crop through causes such as frost in winter or excessive heat in summer is never experienced. It may, therefore, be said that the average annual return from these groves is sufficient to justify the expenditure of any amount likely to be required to effect the

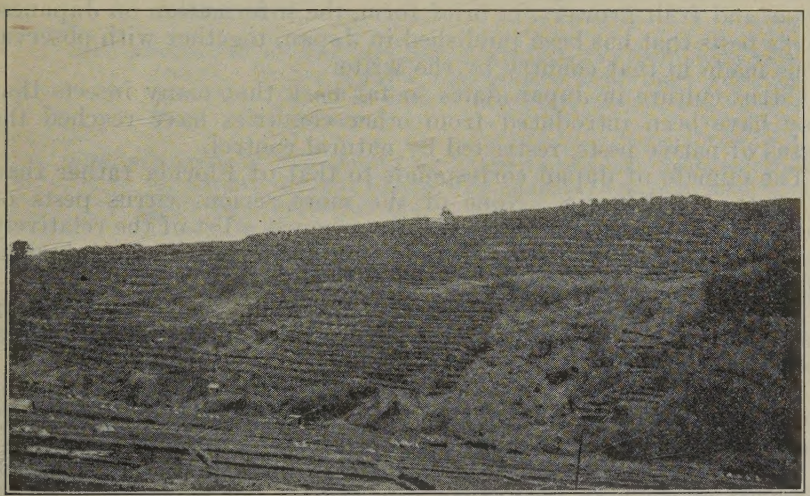

FIG. 5.—Orange groves on terraced hillside, showing conditions under which citrus fruits are normally grown in Japan

control of the pests which at present infest the groves. The greatest problem is the devising of economical means of application to suit local conditions, and this necessitates some form of cooperative organization which does not at present exist.

CONCLUSION

It is a rather notable fact that a great majority of the more serious pests of citrus in the United States are scale insects. Of the five or more in California, all but one are at present found in Japan, but as yet they have shown no indication of becoming a serious menace there. In addition to these there are six or seven species which are as destructive as any of the American forms. Of equal importance are the two species of white flies and the lepidopterous leaf miner. These in many ways present more difficult problems in control than do the scale insects. Although many of these pests,

particularly some of the scale insects and white flies, came originally from the Asiatic mainland and from the Tropics also, it is noteworthy that in southern China these same pests are of little importance. Many of the groves there, where no form of insect control whatever is practiced, are cleaner than most of those in America or Japan which have been fumigated or sprayed at regular intervals. Although this fact is interesting, it in no wise simplifies the problem of control elsewhere. The growers of the United States undoubtedly realize the seriousness of the pests which they already have; yet from the data presented in this bulletin it will be seen that equally dangerous species not yet established here are known elsewhere and that the most thorough and painstaking efforts are needed to prevent their entrance.

SUMMARY

This bulletin is designed to make accessible to American entomologists and fruit growers, in brief form, the information on Japanese citrus pests that has been published in Japan, together with observations made in that country by the writer.

Citrus culture in Japan dates so far back that many insects that may have been introduced from other countries have reached the status of native pests, restricted by natural control.

The climate of Japan corresponds to that of Florida rather than to that of California. None of the more serious citrus pests of Japan are found as such in California, whereas a list of the relatively unimportant pests of Japan includes practically all of the injurious citrus insects of California and Florida.

The most serious scale insects are the yanone scale, the red wax scale, the orange Pulvinaria, the chaff scale, the aspidistra scale, and Glover's scale.

The small size and the location of the groves render the use of large spraying and fumigating units economically or physically impracticable. No cooperative organizations at present exist.

The survey shows that there are citrus pests in the East which have not as yet been introduced into the United States, and which might prove to be dangerous species here.

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